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TECHNICAL MEMORANDUM 226

ROCKET SLED IMPACT TESTS OF BULK CONTAINERS FOR ETIOLOGIC AGENT STORAGE AND SHIPPING

Edward L. Trey

APRIL 1971

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Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Department of the Army Fort Detrick Frederick, Maryland 21701	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

ROCKET SLED IMPACT TESTS OF BULK CONTAINERS FOR ETIOLOGIC AGENT STORAGE AND SHIPPING

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Edward L. Trey

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1971	35	none

8a. CONTRACT OR GRANT NO. b. PROJECT NO. PEMA-51976R1 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) Technical Memorandum 226 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AMXFD-AE-T 50401

10. DISTRIBUTION STATEMENT Distribution limited to U.S. Government agencies only; not cleared for public release under provisions of DoD Directive 5230.9; statement applied April 1971. Other requests for this document must be referred to Commanding Officer, U.S. Army Biological Defense Research Center, ATTN: Technical Information Division, Fort Detrick, Frederick, Maryland 21701.

11. SUPPLEMENTARY NOTES Production and Maintenance Division	12. SPONSORING MILITARY ACTIVITY Department of the Army Fort Detrick Frederick, Maryland 21701

13. ABSTRACT

Tests were conducted to determine the capability of 1,465 ml and 1-, 5-, and 15-gallon etiologic agent container systems to meet the leak test criteria set forth in proposed Code of Federal Regulations (CFR) Title 42, Section 72.25, U.S. Public Health Service, when subjected to impact forces likely to be experienced in an aircraft crash during landing or takeoff. Actual tests were conducted on a rocket sled, controlled to provide impact of test items in a fixed attitude into an essentially unyielding concrete slab (target) at velocities from 145 to 165 feet per second. All containers suffered severe exterior damage; however, the multiple container systems with internal absorbent cushioning did in at least one attitutde prevent leakage of simulated liquid agents to the outermost container.

14. Key Words

Rocket sled impact tests
Etiologic agent container
PHS test criteria
Containers
Testing

DEPARTMENT OF THE ARMY
Fort Detrick
Frederick, Maryland 21701

TECHNICAL MEMORANDUM 226

ROCKET SLED IMPACT TESTS OF BULK CONTAINERS FOR ETIOLOGIC AGENT STORAGE AND SHIPPING

Edward L. Trey

Production and Maintenance Division
COMMODITY DEVELOPMENT & ENGINEERING LABORATORIES

Project PEMA 51976R1

April 1971

FOREWORD

This test, PM 1003, was conducted as part of PEMA Project 51976R1, Container Shipping Biological, to evaluate the performance of several container system designs under test conditions equivalent to an aircraft crash during takeoff or landing.

Testing was conducted at the Naval Weapons Center, China Lake, California from 5 November 1969 to 18 November 1969.

ABSTRACT

Tests were conducted to determine the capability of 1,465 ml and 1-, 5-, and 15-gallon etiologic agent container systems to meet the leak test criteria set forth in proposed Code of Federal Regulations (CFR) Title 42, Section 72.25, U.S. Public Health Service, when subjected to impact forces likely to be experienced in an aircraft crash during landing or takeoff. Actual tests were conducted on a rocket sled, controlled to provide impact of test items in a fixed attitude into an essentially unyielding concrete slab (target) at velocities from 145 to 165 feet per second. All containers suffered severe exterior damage; however, the multiple container systems with internal absorbent cushioning did in at least one attitude prevent leakage of simulated liquid agents to the outermost container.

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FIGURES

TABLES

I. INTRODUCTION*

The XM593, XM594, and XM595 containers were developed to provide a family of containers for shipping various quantities of bulk biological materials without the necessity for overpacking with the CNU-103 and -106 shipping containers during air transit. Shipping safety criteria require that shipping container designs for filling with etiologic agents be proof-tested by impact testing at velocities between 145 and 165 feet per second without evidence of content leakage to the exterior. The most recently dated (3/17/70) proposed U.S. Public Health Service regulation is quoted as follows: "Large Quantity Shipments (Group D) - Any volume of etiologic agent may be shipped provided the container will not permit leakage of viable or toxic etiologic agent outside the outermost shipping container following an impact of the agent-filled container into an unyielding concrete slab, or equivalent, at a minimum impact velocity of 145 to 165 feet per second. For containers that are capable of always being oriented in a specific direction during transport, the impact test will be applied to the forward end of the container. For all other containers the impact test will be applied in three (3) attitudes (top, bottom, side) oriented to the innermost (primary) container that holds the agent."

Design criteria for compliance with Department of Transportation proposed tests for hazardous materials containers were also included in these systems.

During logistics handling in transit, containers filled with viable etiologic agents will in most cases require refrigeration of various degrees. These tests were conducted without their cooling means being present, assuming that such will during actual use afford additional shock attenuation in a true air catastrophe.

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* This report should not be used as a literature citation in material to be published in the open literature.

II. DESCRIPTION

A. CONTAINER, SHIPPING AND STORAGE, ETIOLOGIC AGENT, CAPACITIES 1-, 5-, AND 15-GALLON, XM593; XM594; XM595

These containers (Fig. 1, 2, and 3) are considered as systems consisting of nested separate steel and plastic containers interspaced with liquid- and energy-absorbing materials. The primary containers are liquid-filled to within 10% of their visible capacity. All containers comprising the system are sealed air-tight with their inherent and supplementary closure devices. The physical characteristics of these three systems are:

	XM593	XM594	XM595
Length, in.	20	28	49
Diameter, O.D., in.	14	19	23
Gross weight, lb.	42	128	288
Number of containers in assembly			
Steel, each	2	3	3
Plastic, each	1	1	1
Net fill, gal.	1	5	15

B. CONTAINER, 1,465 ML, TYPE 3

This container is similar in design to those described in Section II. A above except that the steel components are light-gauge food and paint containers packed into a fiberboard box (Fig. 4). Physical characteristics are:

Length, in.	10.75
Width, in.	10.75
Depth, in.	12.25
Gross weight, lb.	11
Number of containers in assembly	
Steel, each	2
Fiberboard, each	1
Net fill, ml	1,400

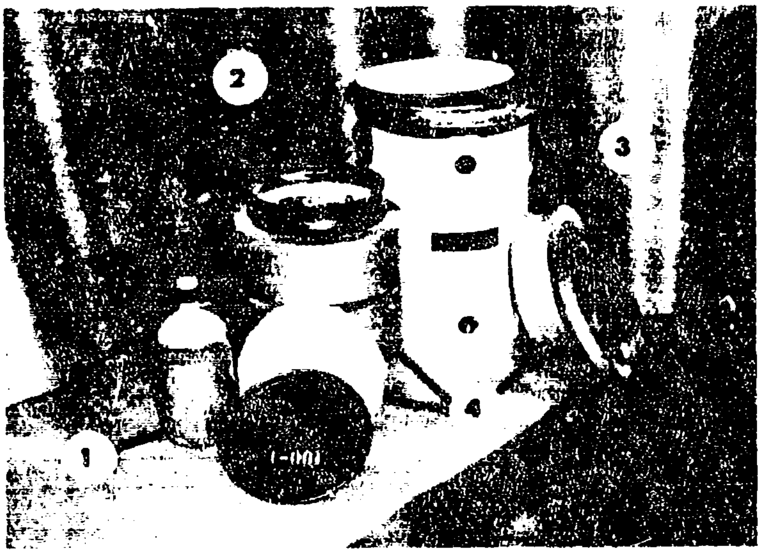

FIGURE 1. Components for XM593, 1-gal Capacity System. (1) Primary container, (2) intermediate container, (3) outer container, (4) blocking and cushioning. Non-particulate liquid absorbent cushioning material is uniformly distributed around primary container.

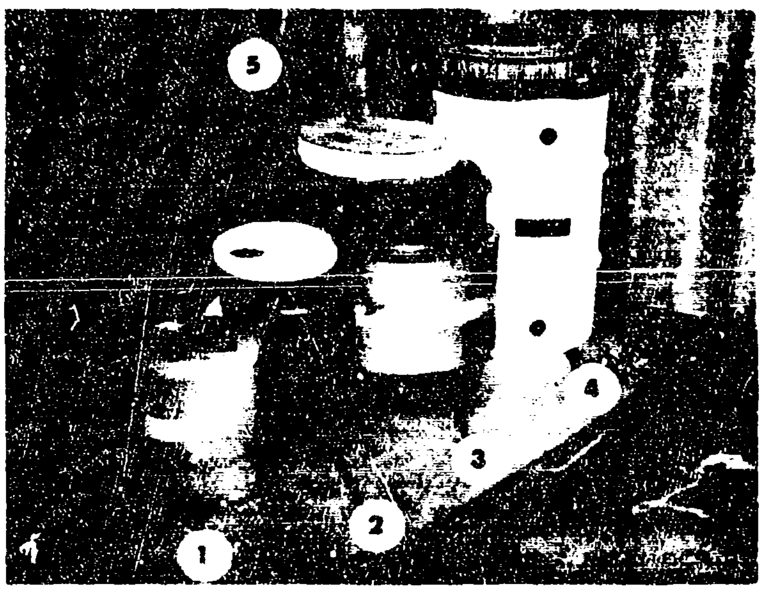

FIGURE 2. Components for XM594, 5-gal Capacity System. (1) Primary container, (2) protective shell for primary container, (3) intermediate container, (4) outer container, (5) blocking and cushioning. Non-particulate, liquid absorbent cushioning material is uniformly distributed around primary container.

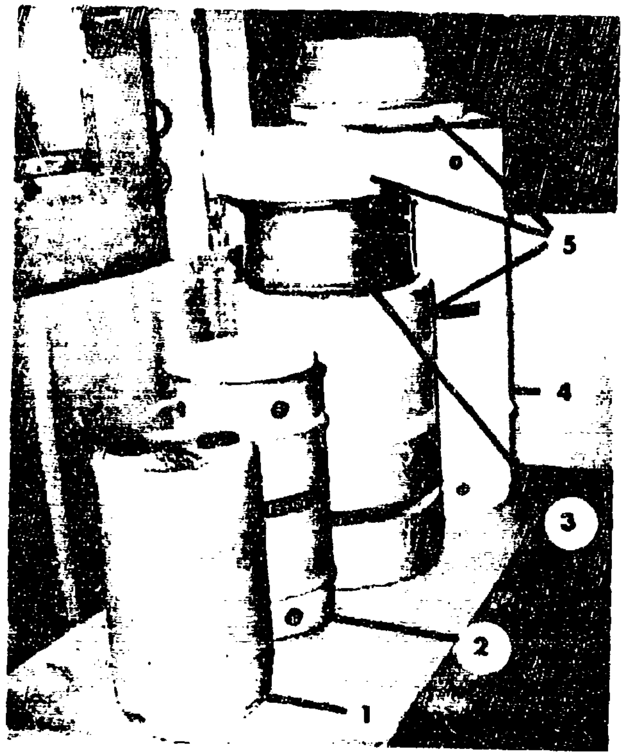

FIGURE 3. Components for XM595, 15-gal Capacity System. (1) Primary container, (2) protective shell for primary container, (3) intermediate container, (4) outer container, (5) blocking and cushioning. Non-particulate, liquid absorbent cushioning material is uniformly distributed around primary container.

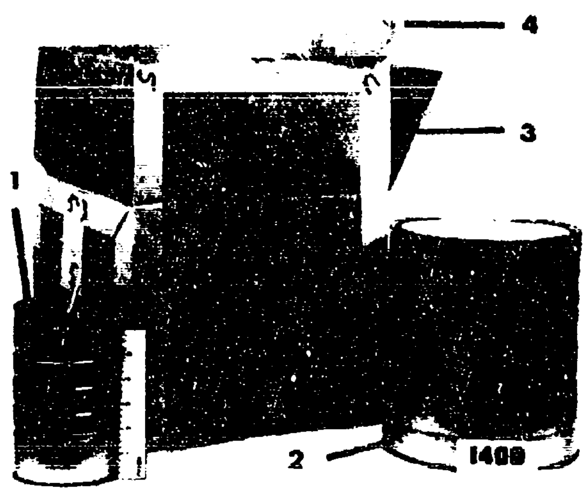

FIGURE 4. Components for 1,465-ml Type 3 System. (1) Primary container, (2) intermediate container, (3) shipping container, (4) absorbent cushioning.

III. TEST EQUIPMENT, TARGET, AND INSTRUMENTATION

A. EQUIPMENT

Impact tests were conducted on the B-4 rocket sled track facility at Naval Weapons Center, China Lake, California. A 120-foot length of track between the breech and a specially constructed impact target was sufficient to achieve the velocity for the desired impact. The test vehicle (Fig. 5) provided a 28- by 72-inch steel bed for mounting the test items. A Model 2801 guillotine*, Figure 5, severed the steel fastening cable prior to impact. Propulsion was provided by HVAR or ZUNI, solid rocket propellant motors.

* Holex Inc., San Juan Road, Hollister, Calif.

FIGURE 5. Rocket Sled with Item Secured for Test Run. (1) Propulsion rockets, (2) transmitter, (3) track coil energizing magnet, (4) guillotine cable cutter.

B. IMPACT TARGET

Three reinforced concrete blocks (Fig. 6), each 12 by 4 by 4 feet with a total weight of 43 tons, were placed in tandem upon a pair of 8-inch by 12-foot steel I beams. Each I beam rests upon three steel-encased concrete columns 20 inches in diameter by 6 feet long, with 3 feet set underground. All components are welded together. A 12- by 4-foot by 1/2-inch-thick steel plate is affixed to the impact side of target.

C. ELECTRONIC INSTRUMENTATION

Accelerations and velocities were obtained with sled-borne transmitting devices via landline systems. A track coil system was energized by magnets mounted on the sled to measure impact velocity (Fig. 5). An ENDEVCO* Model 2264 AMI (half bridge piezo-resistive) accelerometer was mounted 180 degrees opposite the impact side on the exterior of one of each side of the container (Fig. 7) to measure representative decelerations. A PDM/FM** telemeter system transmitted the data obtained to provide an oscillographic record. A typical recording is shown on Figure 8.

D. PHOTOGRAPHIC INSTRUMENTATION

Visual assessment of damage was aided by positioning ground photographic cameras off track and on portable overhead mounts above the track. Three 16-mm, 4,000 fps Fastex cameras, located one on each side and above target area recorded moment of impact on color film. Another camera positioned at an oblique angle to the rear of target recorded approach of test sled at 400 fps. A layout of the immediate test area is shown on Figure 9.

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* Endevco Corp., subsidiary of Beckman, Dickinson Corp., 801 South Arroya Parkway, Pasadena, Calif.

** Pulse-duration modulated/frequency modulated

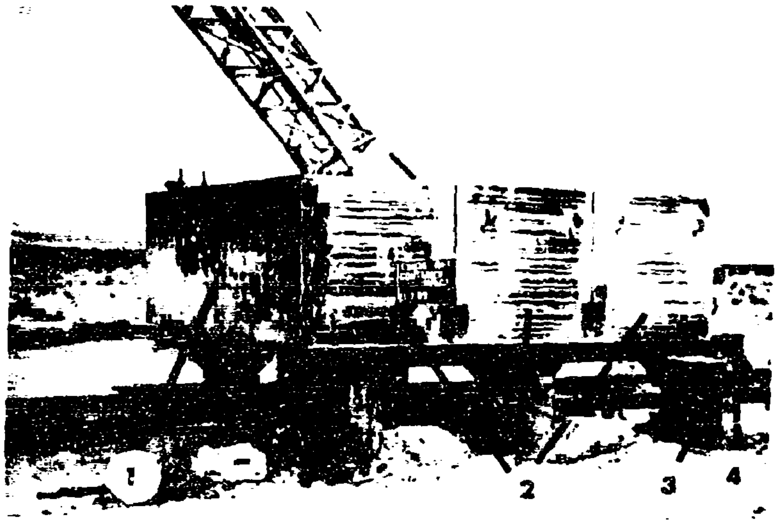

FIGURE 6. Impact Target, an Unyielding Concrete Slab. (1) Steel plate, (2) reinforced concrete blocks, (3) steel-cased concrete columns, (4) steel I beam.

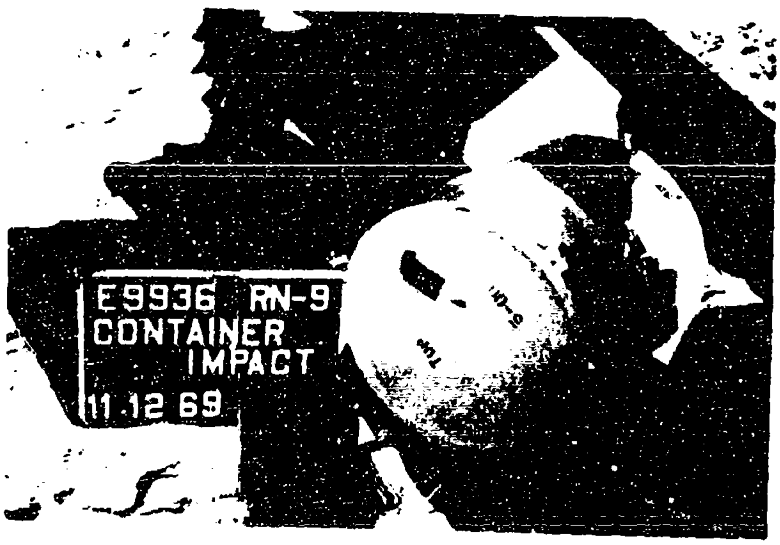

FIGURE 7. Test Item After Impact Showing Accelerometer Still in Place.

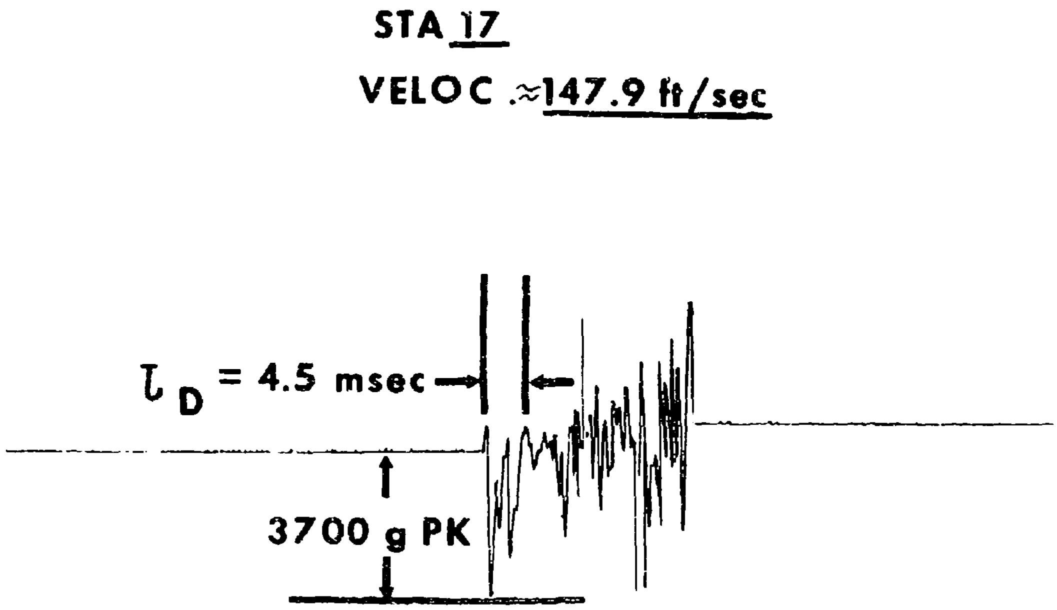

FIGURE 8. A Typical Telemetered Accelerometer and Velocity Recording. (Run 5)

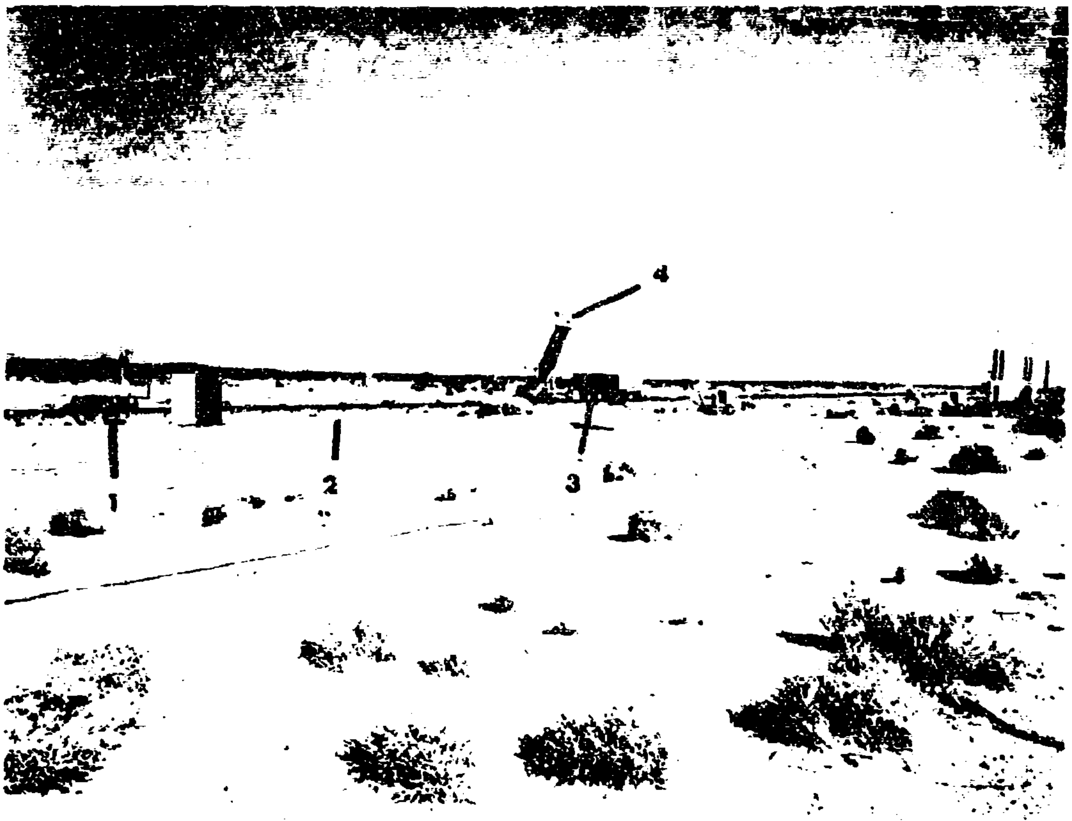

FIGURE 9. Layout of Test Area. (1) Rocket sled, (2) track, (3) impact target, (4) overhead Fastex camera.

IV. TEST PROCEDURES

A. LEAK TESTS

During assembly all container components comprising each system except the 1,465-ml size were tested for air leakage at 5 psig in accordance with the pneumatic pressure technique of Method 241, Federal Test Method Standard 101. All metal containers were fitted with valves for pressurizing to test pressure and subsequent relief of pressure. These were auxiliary tests to insure non-leaking components for subsequent impact testing. Inasmuch as all containers either passed the initial test or were made leak-tight, no further comments are forthcoming. It was noted, however, during disassembly of test items after impact that considerable pressure remained in some of the intact containers. This pressure increase above ambient was due in part to the reduced volume of the containers resulting from impact, but failure in one or more cases to relieve leak test pressure is not discounted.

B. VIBRATION TESTS

One container of each size except the 1,465-ml was vibrated in each potential shipping attitude in accordance with Method 279, Federal Test Method Standard 101 (Fig. 10). The maximum vibration frequencies for each system were: 1-gal capacity - 500 Hz; 5-gal capacity - 443 Hz; 15-gal capacity - 50 Hz. The actual test envelope is shown on Figure 11. No visually observed happenings or accelerometer-recorded data provided information of sufficient significance to report findings beyond mentioning successful performance of these tests.

C. ROCKET SLED IMPACT TESTS

Five replicates of each size system in each of three different attitudes were impacted* against the target (Fig. 6) at velocities indicated in Table 1. (Run 4 aborted because the container was inadvertently left empty.) After impact, the test items were left undisturbed at their final point of rest for five minutes; then the exterior container and surrounding area were examined and assessed visually for extent of liquid spillage. Test items were them removed from the track area in essentially the same attitude at which they came to rest for an additional 15-minute period of visual observation away from the test track. Container systems were then disassembled for assessment of internal damages. Pertinent findings are recorded in Table 1. Photographs of typical significant results are shown in Figures 12 through 24.

* Colored movie film (16-mm), both in slow motion and real speed, covering impact testing is available in Safety Directorate files of Fort Detrick.

FIGURE 10. Vibration Test Installation. 15-gal system in crate mounted on Bruel&kjaer Model 1025 Vibration Exciter. Range: Acceleration 1,000 g; frequency, 5 Hz to 10,000 Hz.

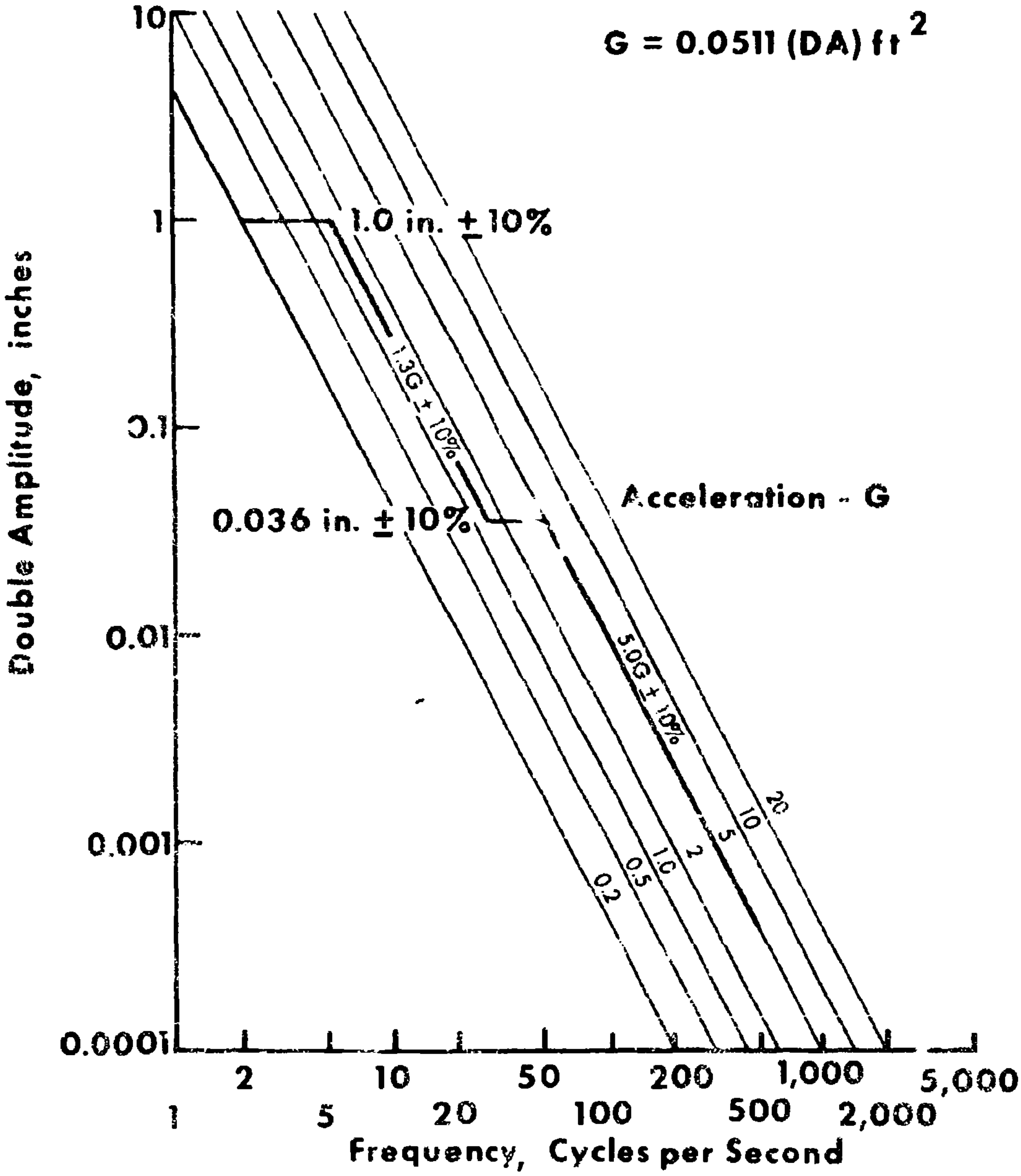

FIGURE 11. Vibration Test Envelope. Test envelope, 2 to 500 cycles per second for vibration (sinusoidal motion) test.

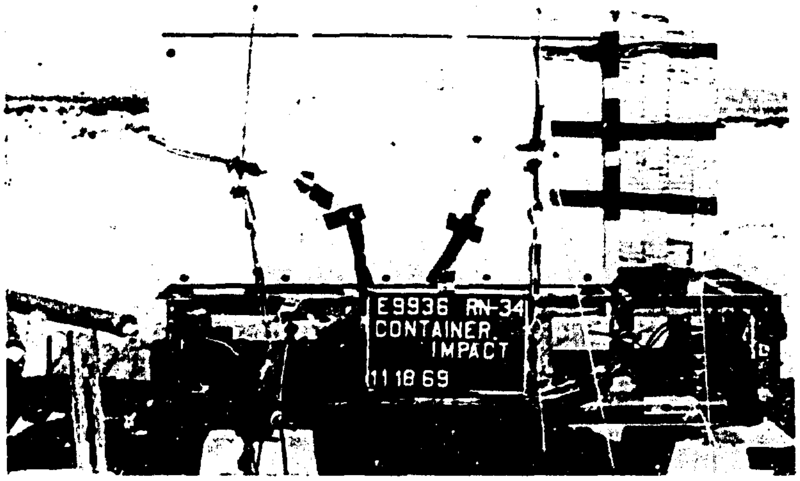

FIGURE 12. Fifteen-Gallon System with Crate and Energy Absorber.

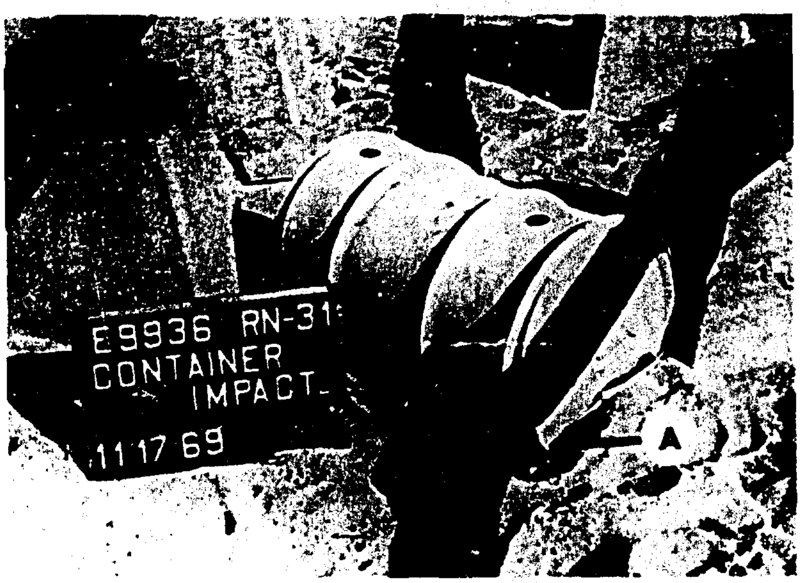

FIGURE 13. Five-Gallon System at Rest After Side Impact. A - area of leak.

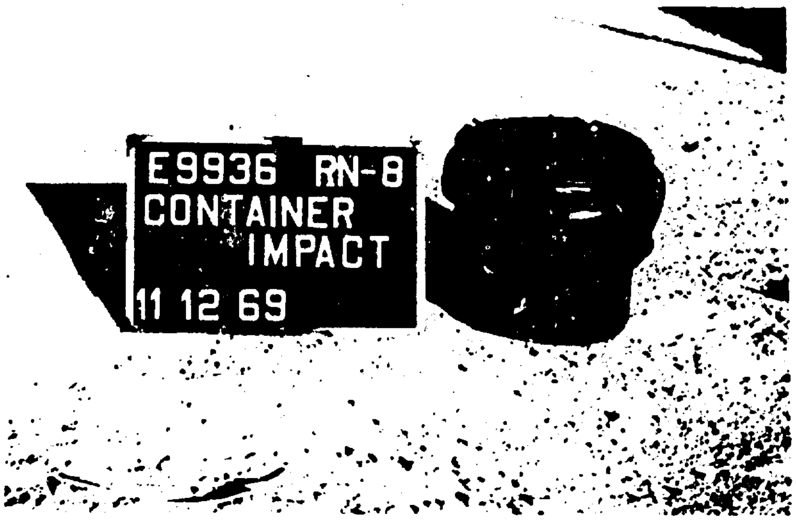

FIGURE 14. Side Seam Failure of Light-Weight Metal Drums. Component Item 2 as shown in Figure 2 for the XM594, 5-gal capacity system.

FIGURE 15. Typical Damage to the 1,465-ml System Bearing Impact on the Top.

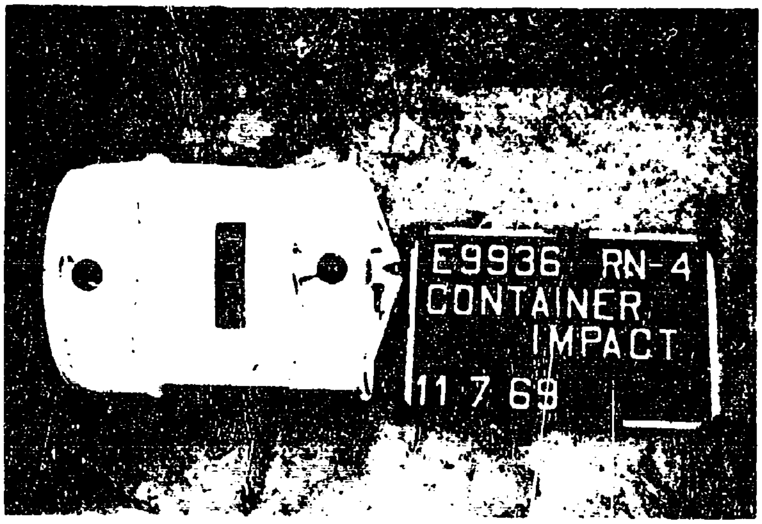

FIGURE 16. Typical Damage to the 1-gal System Bearing Impact on the Top.

FIGURE 17. Typical Damage to the 1-gal System Bearing Impact on the Bottom.

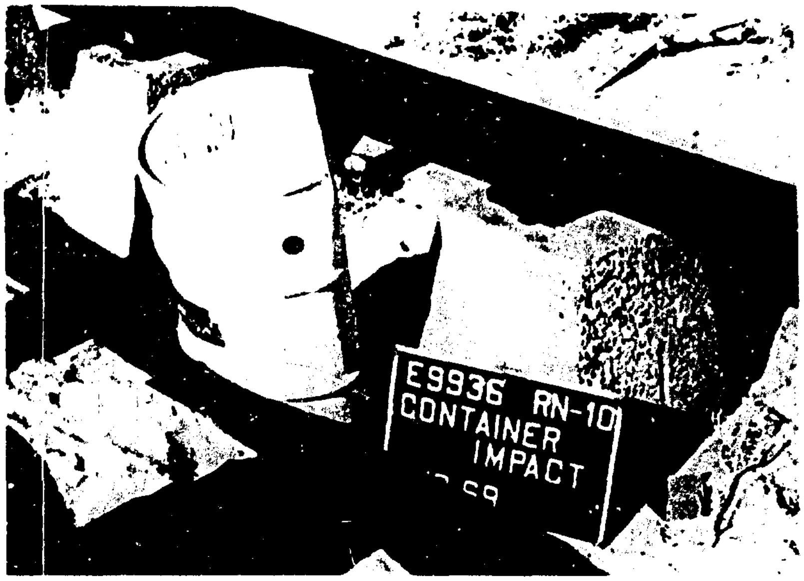

FIGURE 18. Typical Damage to the 5-gal System Bearing Impact on a Side.

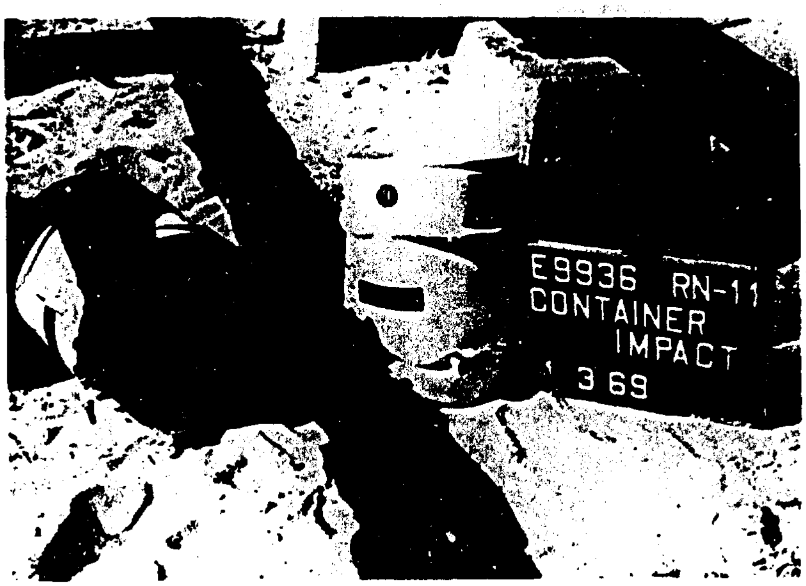

FIGURE 19. Test Run of Two 1-gal Systems Illustrating Shearing Effect of Target on Bolt Ring Closure.

FIGURE 20. Typical Damage to the 1,465-ml System Resulting from Fouling During Impact.

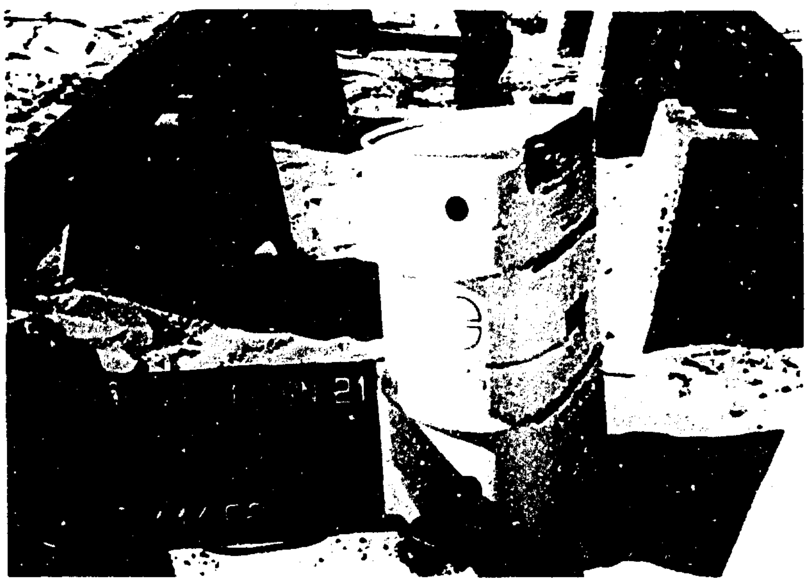

FIGURE 21. Full View of Impact Side Showing Typical Damage to the 5-gal System.

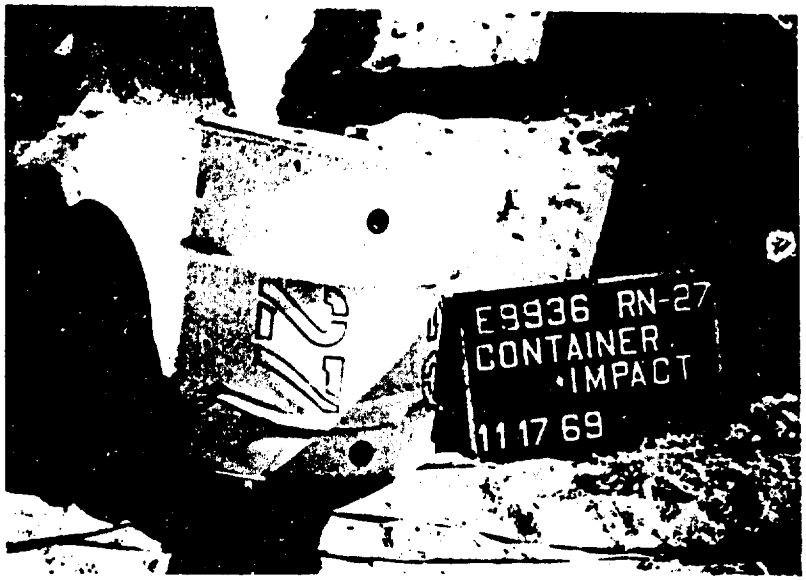

FIGURE 22. Typical Damage to the 5-gal System Bearing Impact on the Bottom.

FIGURE 23. Fifteen-gallon System Impacted on Bottom.

FIGURE 24. Impact Effect of a Crated 15-gal System.

TABLE 1. ROCKET SLED IMPACT TEST DATA

Rocket Sled Run	Container Capacity	Test Item	Attitude	Container Wt, lb.	Container Velocity, ft/sec	Container Compression, in.	Accelerometer Data, g	Rebound, ft	First Leak	Damage Causing Leakage	Remarks
1	1,465 ml	01	Top	11.7	145.7	N/A	[illegible]	2	4" x ¾" smear on absorbent under flap of side #3 of outer carton.	Primary container split at side seam and seam at impact end.	90% of fluid contained within secondary container. Outer carton flaps opened at both ends.
2	1,465 ml	02	Bottom	11.2	147.0	N/A	2,300	18	Very slight leaks at #3 end of secondary container (non-soldered).	Primary container split at side seam and seam at impact end.	Very nearly all fluid contained within secondary container. Outer carton flaps remained closed.
3[a]	1,465 ml	03	Side	11.2	141.0	N/A	Not Measured	6	Secondary container leaking.	Primary container flattened to approximately 1 inch. Both ends blown out.	Sides 1 and 3 broken open. This container may have been fouled on sled by late release of cable.
5	1 gal	002	Top	39.6	147.0	-	3,700	8	3/8 inch hole torn in primary container at base of neck.	Primary container intact except for 3/8 in. hole. Total leakage approximately 2 qt.	All leaks contained within secondary container.
6	1 gal	005	Bottom	-	-	-	Not Measured	-	Container separated from sled prematurely and was propelled by rocket blast 56 ft to the rear. Damage was negligible. Item was reused for sled run 6R.		
6R[a]	1 gal	005	Bottom	41.2	148.9	-	Not Measured	13	None.	None.	Primary container 100% intact.
7[a]	1 gal	006	Side	41.4	148.6	-	3,900	8	Slight leak at closure bolt of secondary container.	Primary container split, Alu-Seal ruptured. Primary container empty.	Puncture in outer container on impact side indicates that this run may have been fouled by cable.
8	5 gal	004	Top	134.4	154.9	5½	3,500	15	Leakage at closure end of secondary container.	Side seam of primary container split full length.	Very high pressure in secondary container. No leakage through outer container.
9	5 gal	005	Bottom	131.2	155	5¾	2,900	18	None.	None.	Primary container 100% intact.
10	5 gal	006	Side	-	-	-	Not Measured	-	-	-	Container fell off sled before impact. Retied and rerun (see Run 10R). Lost acceleration.

10R[a]	5 gal	006	Side	129.2	153.4	3½	2,400	12	Leakage on ground from closure end of outer container within 5 minutes.	Both ends blown out of primary container.	Test item fouled by tie-down cable.
11	1 gal	007	Top	43.2	162.6	4½	Not Measured	15	None.	None.	Primary container 100% intact.
11	1 gal	008	Top	41.8	162.6	4½	Not Measured	15	Slight leak at cap of primary container. Alu-Seal ruptured. All fluid contained within secondary container.	High pressure in primary container. Alu-Seal failure; otherwise intact.	Slight leak from primary container but very little loss.
12	1 gal	009	Bottom	43.2	162.5	5	Not Measured	15	None.	None.	Primary container 100% intact.
12	1 gal	010	Bottom	41.8	162.5	5	Not Measured.	15	None.	None.	Primary container 100% intact.
13	1 gal	011	Side	42.0	156.3	2	Not Measured	12	Slight leak closure end of secondary container. All contained within outer container.	Both sides split on plastic liner of primary container. Most of leakage contained within secondary.	Ruptures occur 90° to impact side.
14	1 gal	003	Side	42.0	157	-	Not Measured	10	Leakage from closure end of secondary collected in bottom of outer container.	Both sides split on primary container. 90° to impact Alu-Seal failed.	Primary container emptied—no leakage outside of outer container.
15	1,465 ml	04	Top	10.9	156.3	N/A	Not Measured	12	Slight leak at #3 end of secondary container.	Primary container split down seams at side and impact end.	Outer container intact after impact. No leaks to outside.
15	1,465 ml	05	Top	11.0	156.3	N/A	Not Measured	18	Slight leak at both ends of secondary container.	Primary container split down seams at side and impact end.	Same as above.
16	1,465 ml	06	Bottom	11.0	154.9	N/A	Not Measured	18	All leakage contained within secondary container.	Primary container split down seams at side and impact end.	Considerable air pressure in secondary container.
16	1,465 ml	14	Side	11.6	154.9	N/A	Not Measured	18	Same as above.	Same as above.	Same as above.
17[a]	1,465 ml	08	Side	11.6	154.9	N/A	Not Measured	3	Liquid on ground, sled, target, and outside of outer container.	Primary container split at seams on both ends. Secondary container split at soldered end.	This container fouled by tie-down cable.

Rocket Sled Run	Container Capacity	Test item	Attitude	Container: Wt, lb.	Container: Velocity, ft/sec	Container: Compression, in.	Accelerometer Data, g	Rebound, ft	First Leak	Damage Causing Leakage	Remarks
1[illegible][b]	1,465 ml	09	Side	11.8	154.9	N/A	Not Measured	4	All leakage contained within outer container.	Both ends blown off primary container. Both end seams split on secondary container.	Same as above.
18	5 gal	007	Top	138.6	154.2	4	Not Measured	15	All leakage contained within secondary container.	Both sides of primary container split half length 90° to seam.	All fluid lost but all contained within secondary container.
19	5 gal	008	Top	126.2	155.9	-	Not Measured	20	Very slight leak at closure bolt on secondary container.	6" splits each side primary container beginning at bail mounts.	Considerable pressure within secondary container. Leakage approximately 2½ gal.
20	5 gal	012	Side	126.4	154.9	4½	Not Measured	13	Pool forming on ground within 5 minutes.	-	Lid blown off at impact. This container not further disassembled.
21	5 gal	017	Side	126.4	154.9	3½	Not Measured	13	Some fluid between secondary and outer container—none on ground.	-	No leakage past outer container. This container not further disassembled.
22	1,465 ml	010	Top	11.7	155.6	N/A	Not Measured	18	Slight leak at corner (end #3) secondary container. Visible on outside of box but no dripping.	Primary container split down side and impact end seams. Secondary leaking at end #3.	Same as above.
22	1,465 ml	011	Top	11.8	155.6	N/A	Not Measured	15	Slight leak at #3 end of secondary container. None outside.	Same as above.	-
23	1,465 ml	012	Bottom	11.9	153.4	N/A	Not Measured	-	Slight leak from end #1 of secondary container (soldered end). All fluid contained within outer container.	Same as above.	-
23	1,465 ml	013	Bottom	11.7	153.4	N/A	Not Measured	-	Same as above.	Same as above.	-
24[a]	1,465 ml	007	Side	11.7	154.2	N/A	Not Measured	4	Both ends of secondary container leaking.	Primary container flattened and both ends blown out.	Most of fluid absorbed by packing in primary container.

24[a]	1,465 ml	015	Side	11.6	154.2	N/A	Not Measured	4	Fluid splattered on ground and target.	Both ends blown out of primary container. Both ends of secondary container leaking.	Staples pulled out of side seam. Outside container torn entirely open.
25	5 gal	009	Bottom	133.6	153.4	5¼	Not Measured	23	All leakage contained within secondary container.	Primary container split full length adjacent to seam.	Characteristic bulge in secondary container.
26	5 gal	010	Bottom	128.4	154.2	-	Not Measured	16	Same as above.	Same as above.	Same as above.
27	5 gal	011	Bottom	126.8	155.6	-	Not Measured	22	Secondary container leaking at closure bolt. All fluid contained in bottom of outer container.	Same as above.	Considerable pressure in outside container.
28	5 gal	013	Bottom	126.4	156.3	-	Not Measured	25	-	Primary container split but liner intact.	Plastic liner of primary container 100% intact except very small amount of liquid under cap.
29	5 gal	014	Top	128.2	157.8	-	Not Measured	20	No leakage outside secondary container.	Primary container split down sides starting at bail mounts and adjacent to side seam.	All fluid lost from primary container. Very high pressure in secondary container.
30	5 gal	015	Top	128.7	154.9	-	Not Measured	25	Same as preceding.	This sample not disassembled past secondary. Appeared to be same as preceding.	Lid blown off on impact. High pressure in secondary.
31[a]	5 gal	019	Side	128.2	157.1	-	Not Measured	11	21" x 10" pool on ground within 5 minutes.	Not disassembled.	Dent and puncture from guillotine on impact side indicates fouling.
32	5 gal	018	Side	128.6	157.1	-	Not Measured	11	Pool forming on ground within 5 minutes.	Neck of plastic liner blown off, bottom end ruptured on each side.	No apparent fouling.
33	15 gal	005	Bottom	288	166.7	11	2,100	15	All fluid contained within primary metal container. Plastic leaking at sides.	Plastic liner leaking somewhat. Liquid loss approximately 1 gal.	Velocity slightly over high limit.
34	15 gal	003	Bottom	421	156.4	4	2,100	15	-	-	Primary container 100% intact.

a. Containers were fouled by failure of rocket sled attachment cables to release test item completely at moment of impact; in run 6 test item left sled prematurely.

V. TEST RESULTS AND DISCUSSION

Significant minimum data for analyzing results obtained from each rocket sled run are listed in Tables 1, 2, and 3. Initial trial runs provided a preview of performance to be expected for each individual container system. Accelerometer data only were obtained during these trials. Early results indicated sufficient promise of success for continuance of replicate tests.

TABLE 2. PERFORMANCE OF ALL TEST ITEMS BY SERIAL NUMBER

System Size & Ser. No.	Impact Attitude[b]	Visible Evidence of Liquid Leakage: Outer Container	Intermediate Container	Primary Container
1465-01	T	No	Yes	Yes
-02	B	No	Yes	Yes
-03	S	No	Yes	Yes
-04	T	No	Yes	Yes
-05	T	No	Yes	Yes
-06	B	No	No	Yes
-07[a]	S	No	Yes	Yes
-08[a]	S	Yes	Yes	Yes
-09[a]	S	No	Yes	Yes
-10	T	No	Yes	Yes
-11	T	No	Yes	Yes
-12	B	No	Yes	Yes
-13	B	No	Yes	Yes
-14	B	No	No	Yes
-15[a]	S	Yes	Yes	Yes
1-002	T	No	No	Yes
-003	S	No	Yes	Yes
-005	B	No	No	No
-006[a]	S	No	Yes	Yes
-007	T	No	No	No
-008	T	No	No	Yes
-009	B	No	No	No
-010	B	No	No	No
-011	S	No	Yes	Yes
5-004	T	No	Yes	Yes
-005	B	No	No	No
-006	S	Yes	Yes	Yes
-007	T	No	No	Yes
-008	T	No	Yes	Yes
-009	B	No	No	Yes
-010	B	No	No	Yes
-011	B	No	Yes	Yes
-012	S	Yes	Yes	Yes
-013	B	No	No	No
-014	T	No	No	No
-015	T	No	No	Yes
-017	S	No	Yes	Yes
-018	S	Yes	Yes	Yes
-019[a]	S	Yes	Yes	Yes
15-005	B	No	No	No
-003	B	No	No	No

a. Fouled by rocket sled attachment hardware.

b. T = top, B = bottom, S = side.

It was determined during these trials that the 1,465-ml system would be enhanced by adding strapping to the outer container. For this purpose four girthwise reinforced plastic straps were added and justified. The exterior fiberboard boxes were severely deteriorated by excessive dryness but still performed fairly well.

Two design concepts of the 15-gallon system (Figures 5 and 12) were impacted to obtain engineering data for final determination of energy absorber requirements. These limited tests indicated that the initial design of the basic system is adequate to meet prescribed test criteria without protection of an added overpack and energy absorber.

Damage is most severe when cylindrical container systems are impacted with their sides oriented parallel to the target. First of all, attachment of test items to the sled in this attitude to insure positive release at moment of impact is difficult and, although several variations were tried, "hang-ups" did occur. Of the four cylindrical, side-impacted test items that failed to meet the test criteria, three were fouled by attachment cables. The leaks, however, were limited to a liquid trickle from a narrow separation of outer drum covers at a point where body chimes were flattened by the side impact. In no case was there any splatter about the target area and the leakage did not commence until containers came to rest after impact action. Figure 13 shows a typical leak for systems of this size that sustained a side impact.

The innermost metal containers (Item 2, Fig. 2) of the 5-gallon systems proved inadequate. These containers were originally equipped with bail handles that were removed for tests; however, the bail mounts welded to the drum bodies provided an easy starting point for side-wall rupture. Areas adjacent to side-seam welds in thin-gauge container metals are also susceptible to fracture. Figure 14 illustrates this characteristic failure.

The attitudes selected for all tests were in strict accord with the most literal interpretation of proposed regulations. Impacting the top and bottom of a cylindrical container is generally accepted; however, some schools of thought question the validity of selecting a side for a third impact attitude, and impacting a leading edge of the top or bottom of the outer container has been suggested.

A 3-inch clearance was provided for the rocket sled to pass under the target after impact. This imposed a shearing force 3 inches from the bottom of the test item (Fig. 19 and 23). It has been suggested that a full-face impact would be more desirable.

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VI. SUMMARY

Establishment of control measures to insure use of the components and materials of the quality and quantity prescribed by appropriate engineering drawings, coupled with precise assembly and adherence to closure and sealing instructions, should consistently produce systems that meet current statutory requirements.

Thirteen of fifteen 1,465-ml systems met the established criteria. Failure of two others may be attributed to fouling of rocket sled attachment cables. Selection of a better grade of fiberboard material and addition of reinforcement strapping for the outer container would improve this design considerably.

Nine of nine 1-gallon systems met the established criteria. However, three items that impacted on their sides permitted liquid leakage beyond the intermediate container but not beyond the outer container.

Eleven of fifteen 5-gallon systems met the established criteria. The four items that allowed varying small amounts of liquid leakage beyond the walls of the outer container were side impacts and two of these showed evidence of fouling by their rocket sled attachments. The excellent performance of this system on the top and bottom attitude impacts merits consideration for its classification as being capable of orientation in a specific direction during transport as provided for in proposed statutes. Appropriate marking and loading instructions could be utilized to insure the latter.

Two 15-gallon systems were impacted in one attitude only and each met the established criteria. One item consisted of the basic assembly as shown in Figure 3; the second item was fitted with a plywood crate and energy absorber on the impact side (Fig. 12). These two systems were impacted as trials to obtain engineering data, so additional replicates for qualification were not scheduled.

The container systems evaluated by these tests are fully described on the following Fort Detrick drawings (Code Identification 24744):

1-gal XM593 - Drawing SK-D-1966
5-gal XM594 - Drawing SK-D-1939
15-gal XM595 - Drawing SK-D-1949
1,465-ml - Drawings are not available because the project was cancelled before all work was completed.

The accelerometer readings recorded for these tests (1,900 to 3,900 g) indicate impacts of a severity exceeding any expected during an actual aircraft crash. Standard in-flight recorders register a maximum of 1,000 g (FAA TSO C51A).